Heavy Duty Vehicles' CO$_2$ legislation in Europe and VECTO simulation tool

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HDV CO$_2$ in the EU Policy context

Transport within the EU is responsible for around one fifth of our greenhouse gas emissions.

While these emissions fell by 3.3% in 2012, they are still 20.5% higher than in 1990.

Road transport accounts for the vast majority – around 70% – of all transport emissions.
Road transport accounts for 72% of total transport and 95% of total transport when international bunkers are excluded

* Source: Eurostat
Road transport emissions

Estimated CO₂ emission by type of road vehicle

-- Cars and light duty vehicles (vans): 70%
-- Heavy duty trucks, buses and coaches: 30%

* Source: Ricardo-AEA
# Roadmap for the Energy Union (Feb 15)

## ENERGY UNION PACKAGE

### ANNEX

### ROADMAP FOR THE ENERGY UNION


A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy

<table>
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<th>Actions</th>
<th>Responsible party</th>
<th>Timetable</th>
<th>SoS</th>
<th>IEM</th>
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<th>GHG</th>
<th>R&amp;I</th>
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<tr>
<td>2030 Climate and Energy Framework:</td>
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<td>Transport actions</td>
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<td>Fair and efficient pricing for sustainable transport – revision of the Eurovignette Directive and framework to promote European electronic tolling</td>
<td>Commission</td>
<td>2016</td>
<td>X</td>
<td>X</td>
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<td>Review of market access rules for road transport to improve its energy efficiency</td>
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<td>2016</td>
<td>X</td>
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<tr>
<td>Master Plan for the deployment of Cooperative Intelligent Transport Systems</td>
<td>Commission, Member States, Industry</td>
<td>2016</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Review of Regulations setting emission performance standards to establish post-2020 targets for cars and vans</td>
<td>Commission</td>
<td>2016-2017</td>
<td>X</td>
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<tr>
<td>Establishing a monitoring and reporting system for heavy duty vehicles (trucks and buses) with a view to improving purchaser information</td>
<td>Commission</td>
<td>2016-2017</td>
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</table>
Current trends in CO₂ emissions from HDVs are unsustainable.

Between 1990 and 2010 CO₂ emissions are estimated to have grown by about 36%, despite the economic crisis interrupting the previous steady growth.

HDVs account for about a quarter of road transport emissions and around 5% of total EU CO₂ emissions - a greater individual share than international aviation or shipping.
Without action, CO₂ emissions from HDVs are expected to remain at best stable over the long term at around 35% above their 1990 level.

Such ‘no policy change’ outcomes are clearly incompatible with the EU long term objective of reducing greenhouse gas emissions from transport by around 60% by 2050 (vs. 1990 levels).
Lack of market transparency

CO₂ emissions from, and fuel consumption of, cars and vans are established when vehicles are manufactured.

However, there is no system of measurement for CO₂ emissions from HDVs in the EU and this reduces transparency for prospective vehicle purchasers in the EU market.
Absence of a measurement methodology

This lack of knowledge is a barrier to the purchase of more efficient HDVs and is a gap that needs to be addressed.

To this end the Commission has put great effort in recent years into developing the VECTO computer simulation tool to estimate HDVs’ fuel consumption and CO₂ emissions for the whole vehicle.

Accordingly, the first priority is to close the knowledge gap on these emissions and to start their registering and monitoring.
Challenges

Further development of the VECTO simulation methodology; its testing to ensure its accuracy compared to real world emissions and its adaptation as a *downloadable executable file*;

Working with DG GROW to amend the "type approval" legislation to enable the application of VECTO when the vehicle is produced/registered;

Preparing co-decision legislation to require the monitoring and reporting of data when the vehicle is produced/registered.
International competitiveness

EU manufacturers account for over 40% of the global production of HDVs. The Commission's whole vehicle measurement approach is not comparable with those of the US and Japan.

**US:**
The 2011 HDV CO₂ rule issued by EPA does not cover the complete emissions of each vehicle, but only the cabin and chassis parts, in combination with a separate rule on engine emissions. In June 2015, new standards have been proposed to reduce the fuel consumption and GHG of HDVs. The new Phase 2 regulations would be implemented from model years 2018 to 2027, building upon initial standards that cover model years 2014 to 2018.
International competitiveness

Japan:
For its part, Japan has a fuel consumption rule with targets based on the best-performing vehicles. Over the long term the various national legislations are expected to converge, as those addressing emissions of vehicles’ exhaust gases have done.
Need for action

Many countries, such as Japan, the US, Canada and China have already introduced CO₂ standards.

EU companies account for over 40% of the global production of trucks and buses and, while they are fuel efficient, the introduction of greater transparency, to allow purchasers greater choice, would clearly benefit the market.

Commission action in this area is necessary.

Delivering this ambitious agenda will not be easy, and will require major efforts to convince all stakeholders to take rapid action.
CO\textsubscript{2} Standards

Feedback from the consultation on the preparation of a legislative proposal on the effort of MS to reduce their GHG emissions to meet the EU's GHG emission reduction commitment in a 2030 perspective:

**UK:** “We also support the development of CO\textsubscript{2} emission standards for HGVs”

**Slovenia:** “Promoting energy efficiency and overall reducing energy demand, e.g. in transport sector with regard to already identifies caveats in testing vehicles emissions, reviewing the CO\textsubscript{2} emission performance standards for new cars and light-duty vehicles, and new similar standards for HDVs”
**CO₂ Standards**

**Belgium**: “A further tightening of CO₂ emission performance standards for new passenger cars and LDVs, and the adoption of similar standards for HDVs post-2020, as well as other initiatives aimed at the use of alternative fuels and the electrification of the transport system;”

**Netherlands**: “The Netherlands would like to see a comprehensive EU transport policy which aims at a substantial reduction of CO₂ in fuels as well as vehicles. Important components of a comprehensive EU transport policy should be the continuation of the CO₂ reduction target in the Fuel Quality Directive post-2020 and an ambitious CO₂ target for vehicles.”
Simulation tool to calculate both, fuel consumption and CO₂ emissions from the whole vehicle.
Vecto development

- VECTO has been developed by the Commission (DG CLIMA and JRC) with TUG support over the last four years
- ACEA, OEMs and component manufacturers have been also involved and provided key input and test vehicles
- DG CLIMA is the leader for this project
- Further development will take place in the next years.
Passenger cars: Easy to measure CO$_2$
Heavy Duty Vehicles...??????

*Source: ACEA*
HDVs are more complicated than LDVs

- Low, medium, high, long, short cab etc
- 2,3,4,5,6 axles, 4x2, 4x4, 6x2, 6x4, 6x6 etc
- Different tires for each axle, single/twin tires etc
- Same engine but different gear boxes/axles etc
- Rigid, semi-trailer, tractor, coach, bus, citybus etc
- Any combination mentioned above

Millions of types!!!!
HDVs Type Approval

Most requirements are safety-related:

- Cab Strength
- FUP & RUP
- Lateral Protection
- AEBS
- LDWS
- EVSC
- Steering Effort
- Audible warning
- Braking
- Speedometer
- Speed limiters
- Tyres
- Identification of controls
- Windscreen defrosting and demisting
- Indirect vision devices
- Lighting installation
- Spray suppression systems
- Windscreen wiper/washer

*Source: ACEA
The following scheme is applicable to type approve a whole vehicle (2007/46/EC)

1. We need type approved components from our suppliers, issued by their TAA
2. We perform the system certification with any Technical Service /Type Approval Authority
3. We obtain system type approvals from Type Approval Authorities we work with
4. Once the puzzle is completed (around 60 system approvals), the whole vehicle (type) approval can be issued by one Type Approval Authority
5. Once the TA is obtained, the complete vehicles fulfilling this approval shall be registered

This is the description of a EC WVTA step by step approach

Front Underun protection test (UN Reg 93)
Lighting installation validation (UN Reg 48)
Verification of the field of vision (UN Reg 46)

*Source: ACEA*
Regulatory situation in EU

Existing Regulations setting performance standards for:
- **Cars** (Reg. 443/2009), and
- **Vans** (Reg. 510/2011)

Currently no legislation setting performance standards for HDV CO\(_2\) emissions or parts thereof

Current test cycle procedure for HDVs is based on the engine (e.g. for regulation air pollutant emissions), not the whole vehicle
VECTO Graphical User Interface (GUI)
VECTO's modes

VECTO offers a *declaration mode*, where all *generic data* and the *test cycle* are allocated automatically as soon as the *vehicle class* is defined.

An *engineering mode* is also offered, where the user can select and change all input data to allow recalculation of test data e.g. for model validation.
VECTO's characteristics

-- VECTO can do any simulation if given the input data, like in the Proof of Concept, but this is only in the engineering mode.

-- Test cycle file can be replaced and take any cycle or route travelled

-- In general, input files are open and fully described in the manual
VECTO's characteristics

A non-expert will **not** be able to perform a correct simulation for various reasons:

- Access to official data???
- Can always use the templates already loaded in VECTO but results won't be accurate
- Most likely to get wrong results at the end of the simulation
VECTO's characteristics

- Current VECTO includes data for a 12t rigid and a 40t tractor in the declaration mode.
- A 24t coach is also included in the engineering mode in addition to the established default factors.
- These data do not correspond to real vehicles in order to avoid confidentiality issues.
- However, they are realistic data including engine maps and produce realistic output results.
VECTO output

In the *declaration mode* of VECTO fuel consumption and CO$_2$ emissions are automatically calculated for all CO$_2$ test cycles allocated to the vehicle for average payload, full load and empty driving. Results are given in g/km, g/cm$^3$-km and g/ton-km or g/pass-km.

Which of these values will be used in a final certification process is not decided yet.
Components and input data

For the following components, relevant input data for VECTO have to be delivered from standardised test procedures:

-- Vehicle mass
-- Tires (dimensions and rolling resistance coef)
-- Engine (engine fuel flow map)
-- Transmission (transmission ratios, loss maps for gear box and axle, default values optional)
-- Aerodynamic drag (Cd x A, for some vehicle classes generic values can be used)
Components and generic values

For the following components **generic values** are defined, which are allocated by the software VECTO to the vehicle depending on the vehicle class and mission profile.:

- Auxiliaries (alternator, air-compressor, steering pump, cooling fan, Heating Ventilation AC - HVAC)
- Mass of the standard bodies and trailers
- Vehicle payload (truck) or passengers weight (bus)
- Test cycle
**Simulations steps**

- Identification of the vehicle
- Allocation of generic data
- Convert distance based cycle to time based
- Apply driver's assist functions (overspeed, Eco-Roll, Forward looking braking etc.)
- Vehicle longitudinal dynamics
- Generic driver gear-shift model (AMT,AT,MT) to compute rpm
- Interpolation from fuel map, application of "WHTC correction factors"
- Information for customer
- Reporting for TAA
- Data for monitoring purposes
Model structure - Four main modules

- **M1**: Driving Cycle Pre-processing
- **M2**: Driver Pre-processing
- **M3**: Power Calculation
- **M4**: FC Calculation
Model structure - Four main modules

**M1**
Driving Cycle Pre-processing

**M2**
Driver Pre-processing

**M3**
Power Calculation

**M4**
FC Calculation

**M1.1**
Convert cycle to 1Hz time-based

**M1.2**
Convert from variable freq. to 1Hz

**M1.3**
Build new time steps

**M2.1**
Overspeed / Eco-Roll

**M2.2**
Look-Ahead Coasting

**M3.1**
Limit acceleration

**M3.2**
Calculate power at wheels

**M3.3**
Gear shift model

**M3.4**
Calculate engine power

**M3.5**
Start/Stop

**M3.6**
Reduce speed

**M3.7**
Traction interruption

**M4.1**
Interpolate from FC map

**M4.2**
Start/Stop Correction

**M4.3**
WHTC Correction
Mission profiles

**Trucks**
- Urban delivery
- Regional delivery
  - Long haul
  - Construction
- Municipal utility

**Buses and coaches**
- City-bus heavy urban
  - City-bus urban
  - City-bus suburban
  - Interurban bus
  - Coach
Test cycles – Target speed cycles

Pros: gives realistic engine load pattern for all weight/power/transmission combinations
Cons: slightly increased computation time

Truck cycles:
- Long Haul
- Regional Delivery
- Urban Delivery
- Municipal Utility
- Construction

Velocity and gradient over distance
Input data: Test cycles - driver models

Example: long haul cycle

Driver model

Acceleration: limited by full load and max. driver demand

Gear selection with torque interruption

Overspeed function optional eco-roll or none

“Look ahead” braking
Input data: Aerodynamic drag - RRC

Constant speed test (at 2 speeds)
- Rim torque meter
- Anemometer
- Correction for gradient and for vehicle speed variations
- Correction for ambient P and T
- \[ F = F_0 + C_d \times A \times v^2 \times r/2 \]

Important tire and vehicle conditioning for accurate \( C_d \times A \) results.

RRC calculated in these tests not to be used. Official value to be used for monitoring purposes.
Rigid and tractors classification

The generic values are allocated to the vehicle by VECTO automatically depending on the HDV class in which the vehicle falls.

For each class the corresponding test cycles, the standard body or trailer and the payload are defined as well as the data relevant for the simulation of the generic auxiliaries.

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<th>Axle configuration</th>
<th>Chassis configuration</th>
<th>Maximum GVM [t]</th>
<th>kWh</th>
<th>Vehicle class</th>
<th>Long haul</th>
<th>Regional delivery</th>
<th>Urban delivery</th>
<th>Municipal utility</th>
<th>Construction</th>
<th>Standard body</th>
<th>Standard semitrailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4x2</td>
<td>Rigid</td>
<td>&gt;3.5 - 7.5</td>
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<td>R</td>
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<td></td>
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<td>S0</td>
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<td>4x2</td>
<td>Rigid or Tractor</td>
<td>7.5 - 10</td>
<td>1</td>
<td>R</td>
<td>R</td>
<td>R</td>
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<td></td>
<td>B1</td>
<td></td>
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<td>Rigid or Tractor</td>
<td>&gt;10 - 12</td>
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<td>R</td>
<td>R</td>
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<td>4x2</td>
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<td>&gt;12 - 16</td>
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<td>4</td>
<td>R+T</td>
<td>R</td>
<td>R</td>
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<td>6</td>
<td>T+5</td>
<td>T+5</td>
<td>R</td>
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<td>R</td>
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<tr>
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<td>7</td>
<td>T+5</td>
<td>T+5</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
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<td>6x2/2-4</td>
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<td>all weights</td>
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<td>R+T</td>
<td>R</td>
<td>R</td>
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<td>B6</td>
<td>T2</td>
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<td>R</td>
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<td>all weights</td>
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<td>R</td>
<td>R</td>
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<tr>
<td>2</td>
<td>8x6 &amp; 8x8</td>
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<td>all weights</td>
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<td>R</td>
<td>R</td>
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<td></td>
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<td>W8</td>
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</tbody>
</table>

R = Rigid & Body
R+T = Rigid & Body & Trailer
T+5 = Tractor & Semitrailer
\(W = \text{no}(\text{CdA})\) measurement, only vehicle weight and frontal area.

\(^1\)Whether it is sufficient to simulate the truck-trailer combination based on \(\text{CdA}\) for Rigid & Body or the full-vehicle test for aerodynamic drag has to be performed additionally with Rigid & Body & Trailer has to be clarified.
# Vehicles' segmentation

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<th>Class</th>
<th>Cycle allocation</th>
<th>Body/trailer allocation</th>
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<tr>
<td>4×2 - Rigid + (Tractor*)</td>
<td>7.5t - 10t</td>
<td>R (pc)</td>
<td>ST1 (19.5t)</td>
</tr>
<tr>
<td>4×2 - Rigid + (Tractor*) &gt; 10t - 12t</td>
<td>R+T (pc)</td>
<td>R (pc)</td>
<td>B1</td>
</tr>
<tr>
<td>4×2 - Rigid + (Tractor*) &gt; 12t - 16t</td>
<td>R (pc)</td>
<td>R (pc)</td>
<td>B2</td>
</tr>
<tr>
<td>Rigid</td>
<td>&gt; 16t</td>
<td>R+T (14.5t)</td>
<td>ST1 (12.9t)</td>
</tr>
<tr>
<td>Tractor</td>
<td>&gt; 16t</td>
<td>Tr+ST (19.5t)</td>
<td>ST1 (19.5t)</td>
</tr>
<tr>
<td>4×4 - Rigid</td>
<td>7.5t - 16t</td>
<td>R (pc)</td>
<td>B6</td>
</tr>
<tr>
<td>4×4 - Rigid + (Tractor*) &gt; 16t</td>
<td>R (pc)</td>
<td>R (pc)</td>
<td>ST1 (generic weight+CdxA)</td>
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<tr>
<td>3 axles</td>
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<tr>
<td>6×2/2-4 all - Rigid</td>
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<td>R+T (19.5t)</td>
<td>B6</td>
</tr>
<tr>
<td>5×4</td>
<td>10</td>
<td>Tr+ST (19.5t)</td>
<td>ST1 (generic weight+CdxA)</td>
</tr>
<tr>
<td>5×4 - Rigid</td>
<td>11</td>
<td>Tr+ST (12.9t)</td>
<td>ST1 (12.9t)</td>
</tr>
<tr>
<td>5×6</td>
<td>12</td>
<td>Tr+ST (12.9t)</td>
<td>ST1 (generic weight+CdxA)</td>
</tr>
<tr>
<td>5×6 - Rigid</td>
<td>all</td>
<td>R (12.9t)</td>
<td>B6</td>
</tr>
<tr>
<td>6×2</td>
<td>all</td>
<td>R (12.9t)</td>
<td>ST1 (2-12)</td>
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<td>8×2/8×3/8×3 all - Rigid</td>
<td>all</td>
<td>R (12.9t)</td>
<td>ST1 (2)</td>
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<tr>
<td>EMS 2 axles</td>
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<tr>
<td>4×2 - Tractor</td>
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<td>Tr+ST+T (20.5t)</td>
<td>T2</td>
</tr>
<tr>
<td>EMS 3 axles</td>
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<td></td>
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</tr>
<tr>
<td>5×2 - Tractor</td>
<td></td>
<td>R+O=ST (20.5t)</td>
<td>B6</td>
</tr>
</tbody>
</table>

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*** Weight is maximum gross vehicle weight

Source: ACEA white book
## Busses classification

<table>
<thead>
<tr>
<th>Axles</th>
<th>Axle configuration</th>
<th>Chassis configuration</th>
<th>Characteristics</th>
<th>Maximum GvW (t)</th>
<th>Class</th>
<th>Segmentation and cycle allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4x2</td>
<td>City</td>
<td>Class I + low floor or low entry, no luggage compartment</td>
<td>&lt;18</td>
<td>B1</td>
<td>HU, UR, SU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interurban</td>
<td>Class II + luggage compartment and/or floor height &lt; 0.9m</td>
<td>&lt;18</td>
<td>B2</td>
<td>IU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coach</td>
<td>Class III + floor height ≥ 0.9m and/or double decker</td>
<td>&lt;18</td>
<td>B3</td>
<td>CO</td>
</tr>
<tr>
<td>3</td>
<td>6x2</td>
<td>City</td>
<td>Class I + low floor or low entry, no luggage compartment</td>
<td>&gt;18</td>
<td>B4</td>
<td>HU, UR, SU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interurban</td>
<td>luggage compartment and/or floor height ≤ 0.9m</td>
<td>&gt;18</td>
<td>B5</td>
<td>IU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coach</td>
<td>floor height ≥ 0.9m and/or double decker</td>
<td>&gt;18</td>
<td>B6</td>
<td>CO</td>
</tr>
</tbody>
</table>
Simulation of engine power

Simulation of engine power:

\[ P_e = P_{\text{roll.}} + P_{\text{air}} + P_{\text{acc}} + P_{\text{grad}} + P_{\text{transmission}} \]

Vehicle specific:
- \( C_d^*A \)
- \( m^*g^*\sin\alpha \)
- Vehicle specific transmission:

Vehicle + tire specific:
- \( m_{\text{vehicle}}, m_{\text{load}} \)
- RRC from drum tests

Vehicle + tire specific:
- Component specific loss
- Component specific loss maps possible

Simulated power Judith (tire \( \times \pi \))

Vehicle transmission ratios
- \( i_{\text{gear}}, i_{\text{axle}} \)

FC interpolated from engine map in 1Hz

DON'T PANIC!
Shares of energy consumption

**EURO V semitrailer 28 t**

- Engine brake: 2.4%
- Sum service brakes: 7.5%
- Drivetrain losses: 6.5%
- Auxiliaries: 5%
- Rolling resistance: 25.2%
- Air resistance: 53.8%

**EURO V city bus**

- Drivetrain losses: 25.6%
- Rolling resistance: 25.6%
- Air resistance: 74.1%

**Must be included:**
- *** Air resistance
- *** Rolling resistance
- *** Engine efficiency
- +transmission ratios

**Shall be included:**
- ** Transmission losses

**Should be included as far as possible:**
- * Auxiliaries
- * Power consumers

Source bus: Marx, 2011
Proof of Concept activity

Scope:
- Prove that simulation based monitoring can deliver results that accurately reflect fuel consumption and performance of modern HDVs
- Verify the validity and soundness of the approach
- Extensive measurements concluded February 2013
- Joint Commission-ACEA activity

Included
- 2 HDVs provided by DAF and Daimler
- Proving ground testing (Iveco’s circuit)
- Chassis dyno testing (JRC)
- On - road / PEMS testing (JRC)
- Engine test bed testing (JRC)
<table>
<thead>
<tr>
<th>Equipment used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Torque measurement</strong></td>
</tr>
<tr>
<td>Wheel rim (Actros)</td>
</tr>
<tr>
<td>Axis (CF75)</td>
</tr>
<tr>
<td><strong>Zeroing</strong></td>
</tr>
<tr>
<td>Daily basis to eliminate drift</td>
</tr>
<tr>
<td><strong>Positioning / speed</strong></td>
</tr>
<tr>
<td>High precision GPS (Actros)</td>
</tr>
<tr>
<td>Sensors at fixed points on ground (CF75)</td>
</tr>
<tr>
<td><strong>Wind speed and wind angle</strong></td>
</tr>
<tr>
<td>Ultrasonic Wind Anemometer (both)</td>
</tr>
<tr>
<td><strong>Ambient temperature, humidity, pressure</strong></td>
</tr>
<tr>
<td>Weather station installed on board (both)</td>
</tr>
<tr>
<td><strong>Fuel consumption</strong></td>
</tr>
<tr>
<td>OEM integrated flow meter (both)</td>
</tr>
<tr>
<td>AVL KMA flowmeter (where possible)</td>
</tr>
<tr>
<td><strong>Vehicle mass</strong></td>
</tr>
<tr>
<td>JRC’s balance</td>
</tr>
</tbody>
</table>
Test vehicles-Route
Report's conclusion and follow-up

- Simulated FC was calculated with a range of ±3% from the real world measurements or even less.
- Finalize and validate topics remaining open in the methodology such as gearbox and driveline efficiency, auxiliary units power consumption, automatic gear shifting strategies, mobile air-conditioning simulation for city buses.
- Perform a sensitivity analysis in order to more accurately quantify the uncertainty of the method for different vehicle types/categories.
- Investigate the necessary conditions for expanding the methodology to other HDV categories.
Development of a CO₂ certification and monitoring methodology for Heavy Duty Vehicles – Proof of Concept report

Georgios Fontaras
Contributing authors: Martin Reuse, Stefan Hausberger, Antonius Kies (TUG)
Johannes Hammer, Leif Erik Schulte (TÜV), Konstantinos Anagnostopoulos, Ursang Manfredi, Massimo Carriero and Panagiota Dilani (JRC)

2014

The full report can be found on DG Clima's website

Monitoring CO₂ Emissions from HDV in Europe – An Experimental Proof of Concept of the Proposed Methodological Approach

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² University of Technology Graz
³ European Commission, Directorate General Climate Action (DG CLIMA)

Abstract

The European Commission in joint collaboration with Heavy Duty Vehicle manufactures, the Graz University of Technology and other consulting and research bodies has been preparing a new legislative framework for monitoring and reporting CO₂ emissions from Heavy Duty Vehicles (HDVs) in Europe. In contrast to passenger cars and light commercial vehicles, for which monitoring is performed through chassis dynamo measurements, and considering the diversity and particular characteristics of the HDV market, it was decided that the core of the proposed methodology should be based on a combination of component testing and vehicle simulation. Emphasis is put on accurately simulating the performance of different vehicle components and achieving realistic fuel consumption results. A proof of concept was launched aiming to test and prove that these targets are achievable.

A series of experiments were conducted on 2 different trucks, a Daimler 46ton Euro VI, long haul delivery truck with semi-trailer and a DAF 18 ton Euro V rigid truck. Measurements were performed at the Joint Research Centre’s HDV chassis dynamo labs and on the road. A vehicle simulator (Vehicle Energy Consumption Calculation Tool - VECTO) has been developed to be used for official monitoring purposes and the results of the measurements were used for its validation. As inputs the simulation based methodology considers test track measurement of driving resistances (eg air drag), determination of driver losses (e.g. gearbox), determination of power demand of engine auxiliaries (e.g. cooling fan) and other consumers (e.g. steering pump), measurement of the engine fuel consumption map as extension to the engine's type approval tests (as described in EURO VI legislation). CO₂ emissions of the vehicle are then calculated using the aforementioned input data for predefined representative driving cycles and mission profiles.

For the two Heavy Duty vehicles tested and simulated on the same test route, fuel consumption was calculated always within a ±3% range from the real world measurement, and in several cases even closer than that (in the order of ±1.5%). Given the variability of the actual measurement (σ = 2%), it is concluded that a future certification scheme could be based on vehicle simulation tools.

Introduction

Heavy-Duty Vehicles (HDV) represent about a quarter of the European Union’s (EU) road transport CO₂ emissions and some 6% of the total CO₂ emissions. In spite of some improvements in fuel efficiency in recent years, overall HDV CO₂ emissions are still rising, mainly due to increasing road freight traffic. The need for a strategy addressing CO₂ emissions from the transport sector has been recognized by the European Commission (EC) in its 2010 Strategy on Clean and Energy Efficient Vehicles. Moreover, the EC’s 2011 White Paper on transport (EC 2011) describes a pathway to increase the sustainability of the transport system with technological innovation, enabling the transition to a more efficient and sustainable European transport system.

One key factor for achieving such targets is a robust CO₂ and fuel consumption monitoring method that reflects to the best possible extent the actual performance of the vehicles over real operating conditions and the comparative advantages of different vehicle models and technology packages available in the market. This in turn provides appropriate information to the end user and better supports the introduction into the market of vehicles with lower fuel consumption (AEA-Ricardo 2011). It also allows the collection of valuable information needed for implementing necessary policy measures to facilitate the achievement of the targets set.

While car and van CO₂ emissions (M1-M1) vehicles are being measured according to an agreed method, HDV emissions so far are not measured in a standardized and consistent way. Consequently no reliable baseline as to the actual amount of these emissions exists. To fill this gap, a series of still on-going projects was initiated by EC. Aim of the research performed was the creation of standardized method to quantify and report CO₂ emissions from HDVs. Initial studies and feedback received from OEMs suggested that the approach that best fits the characteristics and particularities of the HDV

20th International Transport and Air Pollution Conference 2014

Published in TAP Conference, Graz, Austria, September 2014
Proof of concept 12t 4x2 rigid, Class 2

EUROCARGO ML120 E25
Wheelbase: 4818mm
Cab: MLC, aerodynamic spoiler
Engine: 185kW, 6cyl, EURO VI
Gearbox: ZF 9S-75TO
Rear Axle: AM MS10, ratio 1:4.68
Tires: Continental 245/70R19.5
Payload: 3t (ACEA White book)
Test campaigns

Urban:
- Collection of data on a typical urban mission (24Km) in Turin - Italy
- 11 tests
- Good statistical margin of error of the measured fuel consumption
- Monitored values:
  -- Vehicle and engine speed
  -- Instantaneous and accumulated fuel consumption
  -- Gear and Torque
  -- Acceleration
Correlation with VECTO

Simulated fuel consumption in a typical urban mission is 5.2% less than the real fuel consumption.

Vehicle speed and gear shift had a similar trend.
Further steps

Main topics for trucks are:

- influence of tire RRC on the aerodynamic drag test
- engine test accuracy demands
- enhance the validation method (SiCo test procedure)
- improvement of the software reliability
- test and validation of all parts of the certification procedure and of the entire system
- Automatic gear box model is relevant for some trucks
Further steps

The truck category below 7t is not yet included in VECTO but shall be integrated into future legislation.

It is assumed that the existing method covers the small truck class to a large extent but some technical details may demand different approaches in some simulation and test details and certainly all default data sets have to be elaborated for this new HDV class (mission profiles, loading, generic component data sets).
Semi-Forward LCV Vehicles

Scudo/Boxer/Jumper

Sprinter/Crafter

Master/NV400

Transit

*Source: ACEA*
Cabover "Japanse type" Vehicles

*Source: ACEA*
Cabover "European type" Vehicles

*Source: ACEA*
Vehicle categories N2 and M2

**M1/M2/N1/N2**

- **Light-duty**: Test of the complete vehicles on the chassis-dyno
- **Heavy-duty**: Test of the engine on the engine-bench

(*Only for variant/version of vehicle with RM > 2.610 provided that they also meet the requirements of GHG.*

**Reference Mass**

- **2.4**
- **2.5**
- **2.6**
- **2.7**
- **2.8**
- **2.9**
- **3.0**

**Source:** ACEA
Vehicle categories N2 and M2

Reference Mass (kg)

- 1810
- 1930
- 2040
- 2150
- 2270-I
- 2270-II
- 2270-III
- 1780 kg
- 2080 kg
- 2350 kg
- 2550 kg
- 2750 kg

*Source: ACEA*
Timeline (trucks)

- VECTO development: on-going

- Dissemination and trials: from 2013 to mid-2016

- Preparation of possible legislative proposals: 2015-2016

- Possible first reporting year: 2018
Thank you for your attention

- I will be happy to address your questions
- VECTO demonstration will follow
- More info can be found at: http://ec.europa.eu/clima/policies/transport/vehicles/heavy
- Contact details:
Dimitrios SAVVIDIS: dimitrios.savvidis@ec.europa.eu